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The Detection and Nature of the Baryonic Dark Matter

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ABSTRACT

Since the initial baryonic dark matter detection from quasar microlensing was first announced in 1996, substantial strides have been made in confirming the rapid microlensing signature in the Q0957 system and in other gravitational lens systems. The most rapid event recognized had a 1 % amplitude and a 12-hour duration.

Interpretation of the rapid fluctuations has centered upon three offered explanations; microlensing of fine quasar structure by a population of planet mass astronomical bodies in the lens galaxy, orbiting structures in the accretion disc of the supermassive black hole of the quasar, or dark clouds swarming around the luminous quasar source. The observations, particularly the equal positive and negative fluctuations, seem to strongly favor the cosmological population of planetary mass objects in the lens galaxy.

Of the several ideas advanced for the origin of such a population, the most appealing seems to be their birth at time of recombination 300,000 years after the Big Bang.

Subject headings: Galaxy: halo – baryonic dark matter

1. Introduction and Microlensing Results in Q0957

At the 1997 Sheffield Dark Matter Conference I presented the conclusion that the baryonic dark matter appeared to be a population of planet mass bodies freely roaming in interstellar space of the lens galaxy at redshift z=0.37 (Schild, 1996). This report was received with due skepticism; "that's nice, but it's just Rudy's data for Rudy's quasar." Since that time, the data have been confirmed from re-reduction of the original data frames (Ovaldsen,

2003; Colley and Schild 1999, 2000). These authors have confirmed the brightness estimates and the error estimates, and produced evidence of a microlensing event of 12-hour duration and 1% amplitude (Colley and Schild 2003).

The Q0957 rapid microlensing confirmation was slow in coming because of a conundrum in the detection; in order to detect rapid microlensing on 1-day time scales, the A - B image arrival time delay had to be determined to a tenth of a day, but such an accurate time delay would be difficult to determine because of the rapid microlensing.

This conundrum was broken in the QuOC-Around-The-Clock project wherein a 10-night campaign in January 2000, followed by a repeat campaign in March 2002 (417 days later), with observatories around the globe, maintained constant surveillance of the quasar lens brightness. Thus as the quasar set at Mt. Hopkins in Arizona, it was rising in Hawaii, then in S. Korea, Uzbekistan, Canary Islands, Montreal, and then again in Arizona.

The results of this project were published in Colley & Schild et al (2002, 2003), and produced the time delay 417.09 +/- .07 days, with some discussion about the non-uniqueness of such estimates because the black hole is a light emitting surface with 6 light hour size that is evidently microlensed. The illuminated inner edge of the accretion disc would be a factor of six larger, and outer luminous structure is also evident (Vakulik & Schild, 2003).

With this time delay, the authors were able to go back to observations published previously and demonstrate convincing evidence for a microlensing event of 12 hour duration and 1% amplitude (Colley & Schild, 2003, Figs 1 and 2). Cruder data sets published previously were unable to find such elusive events (Schmidt and Wambsganss, 2000; Alcalde et al 2002).

It is important to put into context the tremendous advance in structure resolution this represents. With overall quasar lensing produced by the $10^{12} M_{\odot}$ mass of the lens galaxy, we produce lens image separations of several arcsec. With milli-lensing, by globular cluster mass bodies, we resolve structure on the milli-arcsec level. Microlensing by individual stars in the lens galaxy resolves the outer structure of a quasar, and nano-lensing by the planetary mass baryonic dark matter in the lens galaxy resolves the internal structure of the quasar at the inner region surrounding the supermassive black hole. At the next DARK MATTER symposium, I expect to report the surface brightness of the black hole event horizon from direct measurement.

2. Microlensing Confirmation in Other Gravitational Lens Systems

During the years when the Q0957 rapid microlensing was being confirmed, additional lens systems were monitored and time delays found, and in all cases, insofar as the brightness monitoring produced adequate data, the microlensing fluctuations were found (Burud et al, 2000, 2001, 2002a, 2002b). The amplitudes and durations found were comparable to those already seen in Q0957. Perhaps the best example is the most recent, HE1104-1805, where Schechter et al (2003) and Ofek and Maoz (2003) found continuous microlensing with typical brightness amplitude of 10% and duration of 60 days. An important conclusion was in agreement with the Q0957 discovery; equal positive and negative brightness events were found.

3. Alternative Explanations of the Data

A fundamental prediction of the gravitational lensing theory is that for microlensing in quasar lens systems, the optical depth to microlensing should be approximately one, and so equal positive and negative events should be seen. This is because the macrolensing producing the two quasar images with arcsec separation produces a strong shear on large angular scales, and the smaller microlensing events will enhance or diminish the shear with about equal probability. So the signature of a cosmologically significant microlensing population should be the equal positive and negative events, as found by Schild (1999) from wavelet analysis in the Q0957 system, and convincingly confirmed in HE1104 (Ofek and Maoz, 2003, Figs. 4, 5).

Fortunately, other explanations have been explored. In a report that very beautifully outlines the general problem, Gould and Miralde-Escude (1997) consider the possibility that the fluctuations are produced by bright point-like sources circulating in the quasar accretion disc and producing brightness spikes when they cross the cusp pattern produced by stars in the lens galaxy G1 of the Q0957 system. This scheme has been further explored for HE1104 by Schechter et al (2003).

These schemes are frustrated by their failure to match the observed properties: 1. They produce highly periodic effects not observed. 2. They do not produce the equal positive and negative events observed and intrinsic to the unit optical depth microlensing case. 3. They require super-relativistic speeds for the bright points, especially for the event of 12 hour duration reported by Colley and Schild. 4. Or the scheme requires thousands of hot spots to get equal positive and negative events, producing large statistical fluctuations not observed. 5. No calculation is given to make plausible the existence of such compact blobs,

each having the luminosity of a galaxy and a size smaller than the quasar's central black hole. 6. Since the equal positive and negative fluctuations are seen in two lens systems, it is not reasonable to imagine balanced bright points and dark clouds.

Another explored possible explanation by Wyithe & Loeb (2003) imagines that the fluctuations are simply caused by dark clouds orbiting the quasar, at about the distance where the emission lines form (to avoid super-relativistic speeds). But the authors note from their simulations that the model does not produce brightness records that look like the observed ones. It also requires dark clouds moving at relativistic speeds, and does not address the problem of why such clouds would not be shredded by differential rotation. Nor is it reasonable to imagine cool dark clouds in the presence of CIII, CIV, and NV.

4. The Origin and Nature of the Baryonic Dark Matter Particles

If we provisionally accept the simplest explanation of the microlensing observations, we must ask what is the origin of the planetary mass particles. In the original Schild (1996) report of their detection, they were called "rogue planets" because contemporaneous sub-mm observations of young pre-planetary disc masses gave estimates of approximately $0.1 M_{\odot}$, and it was easy to imagine that most of this mass escaped to produce a vast population of free-roaming planet mass objects. In the intervening years, the proto-planetary disc mass estimates have declined and the explanation seems less tenable.

Another possible explanation advanced by Carr and students (Barrows and Carr, 1996), of a vast population of primordial black holes, seems not to have received further theoretical or observational support.

By far the most interesting explanation comes from the fluid mechanics community, which questions the neglect of viscosity, diffusion and turbulence in the generally accepted Jeans 1905 acoustical criterion for self-gravitational instability (Gibson 1996, 2000). It is concluded that when the viscosity of the plasma universe undergoes its dramatic decrease at the time of recombination, 300,000 years after the Big Bang, the entire gas universe fragments at Jeans and viscous-gravitational scales to form globular-star-cluster-mass clumps of planetary-mass "primordial fog particles". The publication Gibson (1996) proposing these dark clumps of dark planets as the baryonic dark matter appeared within a month of the independent observational result and "rogue planet" interpretation published by Schild (1996).

Other predictions of the hydrodynamic theory of gravitational structure formation include the top-down fragmentation of plasma starting 30,000 years after the Big Bang to form proto-superclusters, proto-clusters, and proto-galaxies. The massive weakly-collisional

non-baryonic dark matter diffuses to fill the voids between these structures, and fragments after recombination to form large outer-galaxy and outer-galaxy-cluster halos. Star formation occurs by accretion of the dark-matter planets (30 million per star), leaving Oort Cloud size holes in an interstellar medium filled with planets. Evaporation of planets bordering the holes by symbiotic-star (white dwarf and companion) plasma jets prior to SuperNova Ia events provide a source of random systematic SNIa dimming that may be an alternative to the "dark energy" interpretation. Stars and luminous galaxies with large central black holes form rapidly that can explain observations of large red shift quasars and galaxies. Hydro-gravitational theory also explains the missing galaxy fragments expected in hierarchical clustering scenarios.

5. Some Further Consequences of the Baryonic Dark matter Detection

Usually in science, when a major shift in understanding is made, a few misinterpretations of previous data become evident. We summarize a few such apparent shifts in prevalent paradigms now noticed.

The cometary knots in the Helix nebula illustrated and described in O'Dell and Handron (1996) and previous references have been traditionally explained as Rayleigh-Taylor instabilities in the expanding gas shell, or as shock front effects. These explanations are untenable in view of the mass estimates of Meaburn et al, (1998) which demonstrate mass enhancements greater than 1000 over the nebular gas density; these are untenable in the accepted models. We believe that these are instead the primordial dark matter particles of the type seen in quasar microlensing and predicted by hydrodynamics (and called primordial fog particles, PFP's). In this picture, the particles are at rest with respect to the expanding gas shell, whereas in the other models they are expanding with the gas shell. Proper motions can settle the matter, and the available measurements by O'Dell et al (2002) give a measurement of the expansion velocity of only $4.5 \pm 9 km/sec$, where 14 km/sec is the known expansion velocity. Thus measurements presently favor our predicted 0 km/sec, but do not yet confirm our prediction.

The theory of solar system formation is stuck with a rocky planetary core formation process; stones colliding with stones in pre-planetary discs are believed to stick together to form larger rocks, even though this process has never been demonstrated in experiments. We believe that rocky cores of planets, Kuiper belt objects, and Oort cloud objects were formed when the primordial PFP population collected at its center the interstellar dust particles, and then crushed them together when the PFP's froze as the universe cooled below the 20 degree Kelvin freezing point of Hydrogen.

And we also note that our population of primordial particles would have an important effect on the transparency of the universe to the light of quasars and distant supernovae. If particles the sizes and masses of the cometary knots in the Helix nebula are seen (without their tails) to cosmological distance, they would intersect a significant fraction of the light of these large distant objects, explaining the quasar peak at z=1.9 and the dimming of distant supernovae. The complex processes of absorption and refraction by PFP's need to be modeled to see whether the grey extinction model for "self replenishing dust" (Goobar et al, 2002) can be approximated to reproduce the dimming of distant supernovae (Riess et al, 2004).

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